

1                   **POWER MANAGEMENT FOR BATTERY POWERED APPLIANCES**

2                   The present application claims priority to Provisional Application Serial No. 60/234,442,  
3                   filed September 21, 2000, and assigned to the same assignee.

4                                   **Background of the Invention**

5                   **1. Field of the Invention**

6                   The present invention relates to power management for battery powered devices, and  
7                   more particularly, to a power management topology that includes an external AC/DC adapter  
8                   that is controlled by battery charge controller associated with a portable device.

9                   **2. Background Description**

10                  Present battery charging topologies are divided into two separate designs and  
11                  implementation: AC adapters and battery charging topologies.

12                  AC adapters have two present designs:

13                  1) 60 Hz -- Low cost transformers with full wave rectifiers and a filter capacitor. The  
14                  windings of the transformer usually have high resistance that results in a quasi constant current  
15                  source.

16                  2) Hi Frequency -- Promoted as the travel version of AC adapters with high frequency  
17                  usually >100KHz. As reactive impedance is a direct function of frequency ( $X_L = 2 \pi f L$  and  
18                   $X_C = 1/2 \pi f C$ ) for the same impedance L and C are smaller by the ratio of frequencies. For  
19                  example the size of an inductor for 600,000 Hz vs 60 Hz is the ratio of 60/600,000 or 1/10,000 =  
20                  0.0001. These travel versions of AC adapters are designed with high frequency Switch Mode  
21                  Power Supplies (SMPS). Hence the benefits are small size and light weight, highly valued by  
22                  travelers, but may cost more than other types of adapters.

1 Most adapters in use today include PWM circuitry and controllers (including power  
2 switches and DC/DC converter circuitry such as Buck, flyback, boost, bridge, or other type of  
3 converter topology) to generate a regulated output.

4 Battery Chargers in systems like notebook computers, cellular phones and PDA's are  
5 generally used to control battery charging and/or power distribution to a system. Battery  
6 chargers generally have three popular designs:

7 1) Simple switched adapter charger uses a single electronic switch to directly connect  
8 the adapter to the battery. Then turning the switch off when the final charge voltage is reached.  
9 While relatively inexpensive, this type of charger circuitry must use a constant current AC  
10 Adapter generally the heavy, 60 Hz type. The battery charging algorithm is highly  
11 compromised, resulting in long charge times, perhaps never reaching full charge and limited  
12 ability to adapt to multiple battery chemistries like LiIon, NiMH and NiCd.

13 2) Linear regulators -- Creation of a fixed output voltage is developed by dissipating  
14 excess input voltage within the regulating component. This usually results in efficiencies of 50%  
15 or less. The wasted power is dissipated within the regulator increasing the temperature within  
16 the small, tightly enclosed product. Additionally the wasted power significantly shortens the  
17 battery life which is of paramount importance to anyone carrying these products around. The  
18 only benefit for a consumer product with a dead battery is as an expensive piece of exercise  
19 equipment. The benefits of linear regulators are simplicity and low cost. The negatives include  
20 short battery life and high internal temperatures.

21 3) Switchmode Regulators -- As described above, this method uses a switched mode  
22 power supply to efficiently (90 to 95%) convert the input voltage to the battery charge voltage.  
23 Optimum charging algorithms can be applied like constant current mode switching to constant

1 voltage mode. Benefits of this type of design are rapid charging, high efficiency and adaptability  
2 to varying adapters and battery chemistries, but may cost more than linear regulators.

3 Figure 1 depicts a conventional power management topology for a portable device. The  
4 system includes a portable device 10 that includes one or more batteries 30 and one or more  
5 active systems 18, 20, and/or 22 coupled to an AC/DC adapter 12. The adapter 12 operates to  
6 deliver controlled power to both charge the batteries and power any systems coupled thereto. A  
7 battery charger circuit 14 is provided to provide regulated power (voltage and/or current) to the  
8 battery 30 based on, for example, battery charging current, battery voltage, and/or available  
9 power from the adapter 12. Referring to Figure 1A, a block diagram of a conventional battery  
10 charger circuit 14 is depicted. As is well understood in the art, the charger generally includes a  
11 plurality of error amplifiers 34 that monitor battery voltage and/or current and generate an error  
12 signal if the battery voltage and/or current exceed some predetermined threshold. Additionally,  
13 an error amplifier may be included to monitor input power availability and generate an error  
14 signal if the available power from the adapter 12 is exceeded. The charger 14 also includes a  
15 PWM generator and controller 36. The error signals generated by the error amplifiers are  
16 received by the controller 36 and operate to adjust the duty cycle of the PWM generator. The  
17 PWM signal is supplied to power switches and DC/DC converter 38 to generate a regulated DC  
18 source for charging the batteries.

19 Similarly, the AC/DC adapter 12 includes a PWM generator and controller, and further  
20 includes power switches and a DC/DC converter to provide a regulated output power source.  
21 Thus, a redundancy exists since both the adapter 12 and the charger 14 include a PWM generator  
22 and controller, power switches and a DC/DC converter.

1 SUMMARY OF THE INVENTION

2 Accordingly, the present invention provides a power management topology that includes  
3 an external AC/DC adapter that is controlled by battery charge controller. In the exemplary  
4 embodiments, the charge controller includes the error amplifiers to generate a feedback control  
5 signal, while the AC/DC adapter is modified to receive the control feedback signal to regulate  
6 the duty cycle of the PWM generator associated with the adapter. Thus, in the exemplary  
7 embodiments, the need for a PWM generator and controller, as well as power switches and a  
8 DC/DC converter are eliminated in the charger circuit, thereby economizing power topologies, as  
9 well as removing heat-generating portions of a conventional battery charger circuit to the  
10 external AC/DC adapter.

11 System exemplary embodiments include a power management topology for a portable  
12 electronic device, comprising a portable electronic device comprising a rechargeable battery and  
13 a charge controller comprising circuitry generating a feedback signal indicative of battery  
14 voltage and/or battery charging current. The topology also includes an external AC/DC adapter  
15 generating a DC source signal from an AC source, said adapter comprising a PWM generator  
16 generating a PWM signal and controller. The controller receives the feedback signal and adjusts  
17 the duty cycle of the PWM signal thereby adjusting the voltage and/or current value of the DC  
18 source signal.

19 In other exemplary embodiments, the present invention provides an AC/DC adapter  
20 comprising a PWM generator generating a PWM signal, a controller receiving a feedback signal  
21 generated by an external portable electronic device, and a DC/DC converter circuit generating a  
22 DC source signal. The controller adjusts the duty cycle of the PWM signal based on the  
23 feedback signal thereby adjusting the voltage and/or current value of the DC source signal.

1 It will be appreciated by those skilled in the art that although the following Detailed  
2 Description will proceed with reference being made to preferred embodiments and methods of  
3 use, the present invention is not intended to be limited to these preferred embodiments and  
4 methods of use. Rather, the present invention is of broad scope and is intended to be limited as  
5 only set forth in the accompanying claims.

6 Other features and advantages of the present invention will become apparent as the  
7 following Detailed Description proceeds, and upon reference to the Drawings, wherein like  
8 numerals depict like parts, and wherein:

9 Brief Description of the Drawings

10 Figure 1 is a block diagram of a conventional power management circuit;

11 Figure 1A is a block diagram of a conventional battery charger circuit;

12 Figure 2 is a block diagram of one exemplary of the power management topology of the  
13 present invention; and

14 Figure 3A, 3B and 3C depict block diagrams of exemplary AC/DC adapter topologies  
15 according to the present invention.

16 Detailed Description of Exemplary Embodiments

17 Figure 2 depicts a block diagram of an exemplary power management topology according  
18 to the present invention. As with the conventional power management topology of Figure 1, the  
19 topology of Figure 2 includes a system 10 powered by an AC/DC adapter 32. However, in this  
20 exemplary embodiment, the adapter 32 is feedback enabled to receive one or more feedback  
21 control signals generated by the error amplifiers associated with the charger. Thus, in this  
22 exemplary embodiment, it is only necessary for the charger to include error amplifiers, and is  
23 thus generalized as a charge controller 24. The charge controller 24 includes a plurality of error

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1 amplifiers that monitor battery voltage and/or current and generate an error signal if the battery  
2 voltage and/or current exceed some predetermined threshold. Additionally, an error amplifier  
3 may be included to monitor input power availability and generate an error signal based on the  
4 charging requirement of the battery balanced with the power requirement of the active system.  
5 These error signals are generally defined herein as feedback control signals 26, and are used to  
6 adjust the duty cycle of a PWM generator. One such battery charger topology is disclosed in  
7 U.S. Application Serial No. \_\_\_\_\_, entitled "Voltage Mode, High Accuracy Battery Charger",  
8 assigned to the same Assignee, and hereby incorporated by reference in its entirety. In the '\_\_\_\_  
9 application, feedback control signals are generated for battery voltage, battery charging current,  
10 and/or available power from the DC source to adjust the duty cycle of the PWM generator,  
11 thereby adjusting power delivered to the battery. Other charge topologies are well-known in the  
12 art, and all such battery charging circuits are deemed interchangeable and equivalent circuitry for  
13 the charge controller 24 of the present invention.

14 As set forth above, a conventional switched mode power supply (SWPS) AC/DC adapter  
15 includes PWM circuitry (generator and controller), power switches and DC/DC converter  
16 circuitry for generating a constant DC source. In the exemplary embodiment, the PWM  
17 controller of the AC/DC adapter is adapted to receive the feedback information generated by the  
18 charge controller 24 to adjust the DC output.

19 Figures 3A, 3B and 3C depict exemplary communication topologies to facilitate  
20 communication between the charge controller 24 associated with the portable system 10 and the  
21 adapter 32 of the present invention. In Figure 3A, the adapter 32' is modified to include a serial  
22 communications interface 38 (e.g., RS232, RS434, Firewire, USB, etc.) to receive a serial  
23 control signal 26' generated by the charge controller. In this embodiment, the feedback control

1 signal generated by the charge control is converted into serial communication data and  
2 forwarded to the adapter 32'. In Figure 3B, the control signal 26'' is an analog signal generated  
3 by the error amplifiers, and accordingly, an appropriate analog interface (e.g., buffer) may be  
4 provided in the adapter 32''. Figure 3C does not utilize a separate control signal line, but rather,  
5 modulates the feedback signal 26''' onto the power line. In this embodiment, both the adapter  
6 32''' and system 10' are adapted with modulation/demodulation circuitry (42 and 44,  
7 respectively) to generate a feedback signal 26''' that is transposed on the power line.

8 Thus, the present invention provides power management topologies that obviate the need  
9 for power circuitry associated with a conventional battery charger circuit, and instead utilize the  
10 power circuitry already present in an AC/DC adapter to generate regulated controllable power to  
11 charge a battery and/or power a portable device. Advantageously, the costs of power switches  
12 and power dissipation within the appliance have been eliminated. The cost of an additional  
13 controller has been eliminated. Printed circuit board space has been saved within the appliance  
14 as there is no need for bulky power switches. Additionally, optimum charge algorithms can be  
15 implemented resulting in short battery charge times with full charge. Those skilled in the art will  
16 recognize numerous modifications to the present invention. These and all other modifications as  
17 may be apparent to one skilled in the art are deemed within the spirit and scope of the present  
18 invention, only as limited by the appended claims.